Booster Energy Spread – Console Application Program

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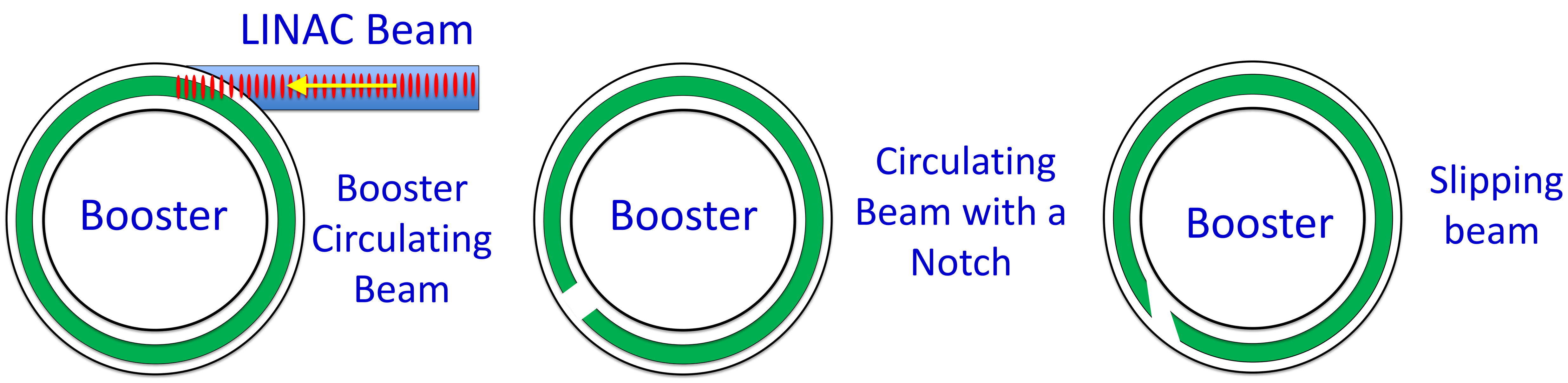
Abstract: We have developed a console application program to measure the total energy spread for the Booster beam at its injection energy of 400 MeV. Upon entering the program following functions can be executed: 1) check if the executing program is safe (all necessary instruments are available to measure the Booster energy spread), 2) set necessary parameters on the TDS7000 scope, 3) execute an ACL script upon permission from MCR crew chief which enables *1-shot* timeline that injects multi-turn beam on $17 into the Booster, moves all the RF gates to a user requested time, creates a *notch* in the injected beam and returns to normal operation, 3) collects WCM data from the scope, 4) analyze the data to extract the beam energy spread and 5) gives graphical output on a separate window for user's decision.



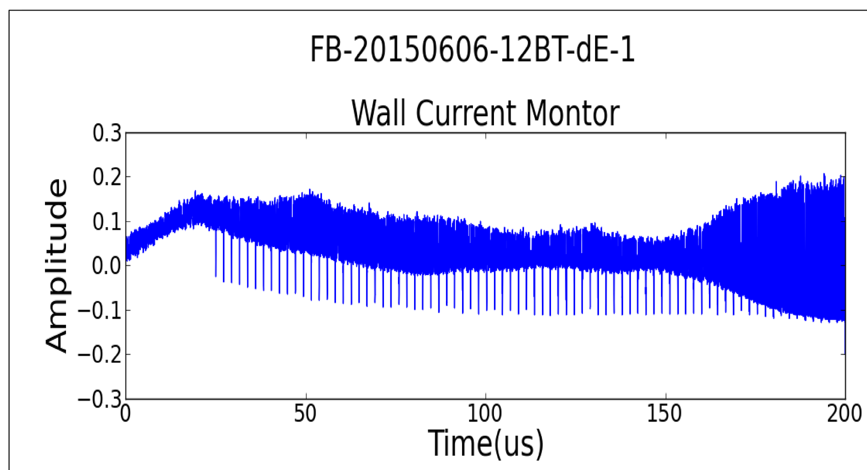


Fig 1: This is raw data of an early notch injection scheme. The icicles are the same notch appearing for every revolution.

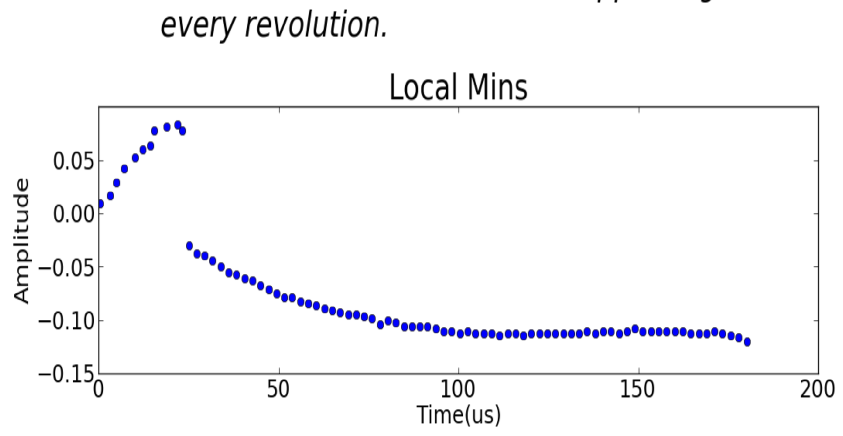


Fig 2: The data is processed to find the first notch.The sudden jump indicates that notch and the following points show the same notch for subsequent revolutions.

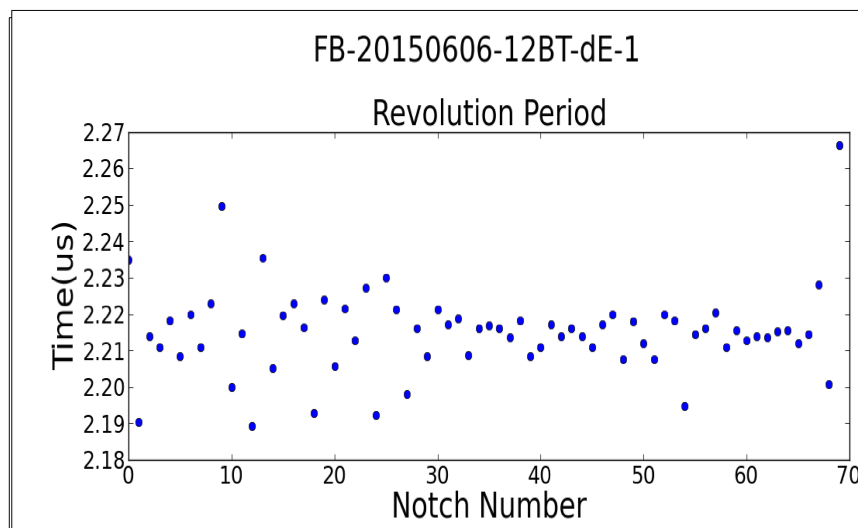


Fig 3: Evolution of revolution period in the first 200 us.

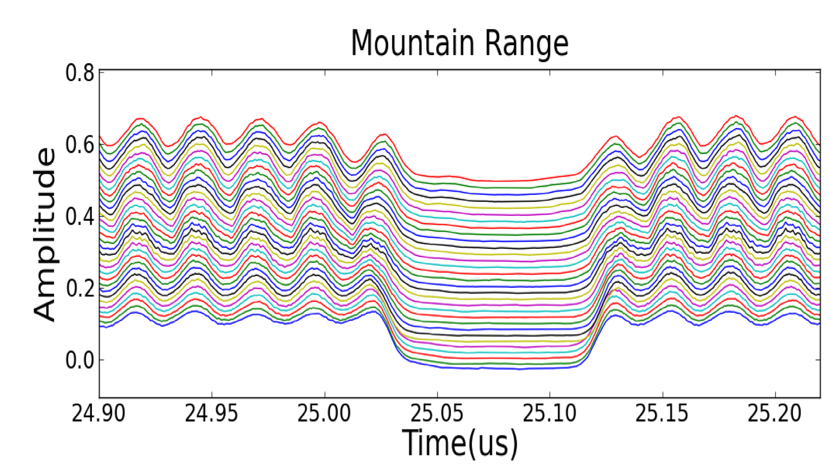
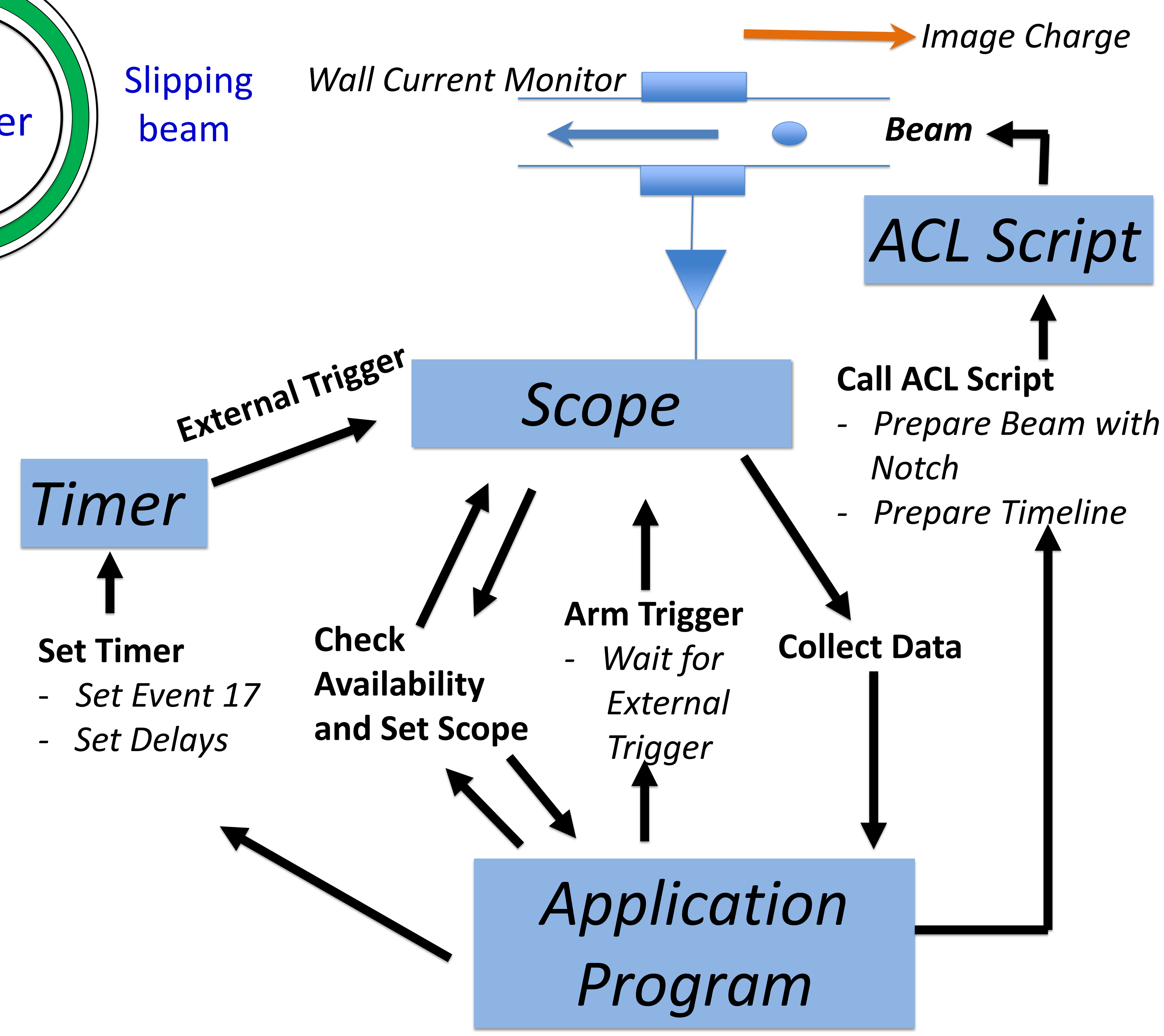


Fig 4: Evolution of the notch filling. Each trace is for consecutive revolutions.

Program Flow Chart

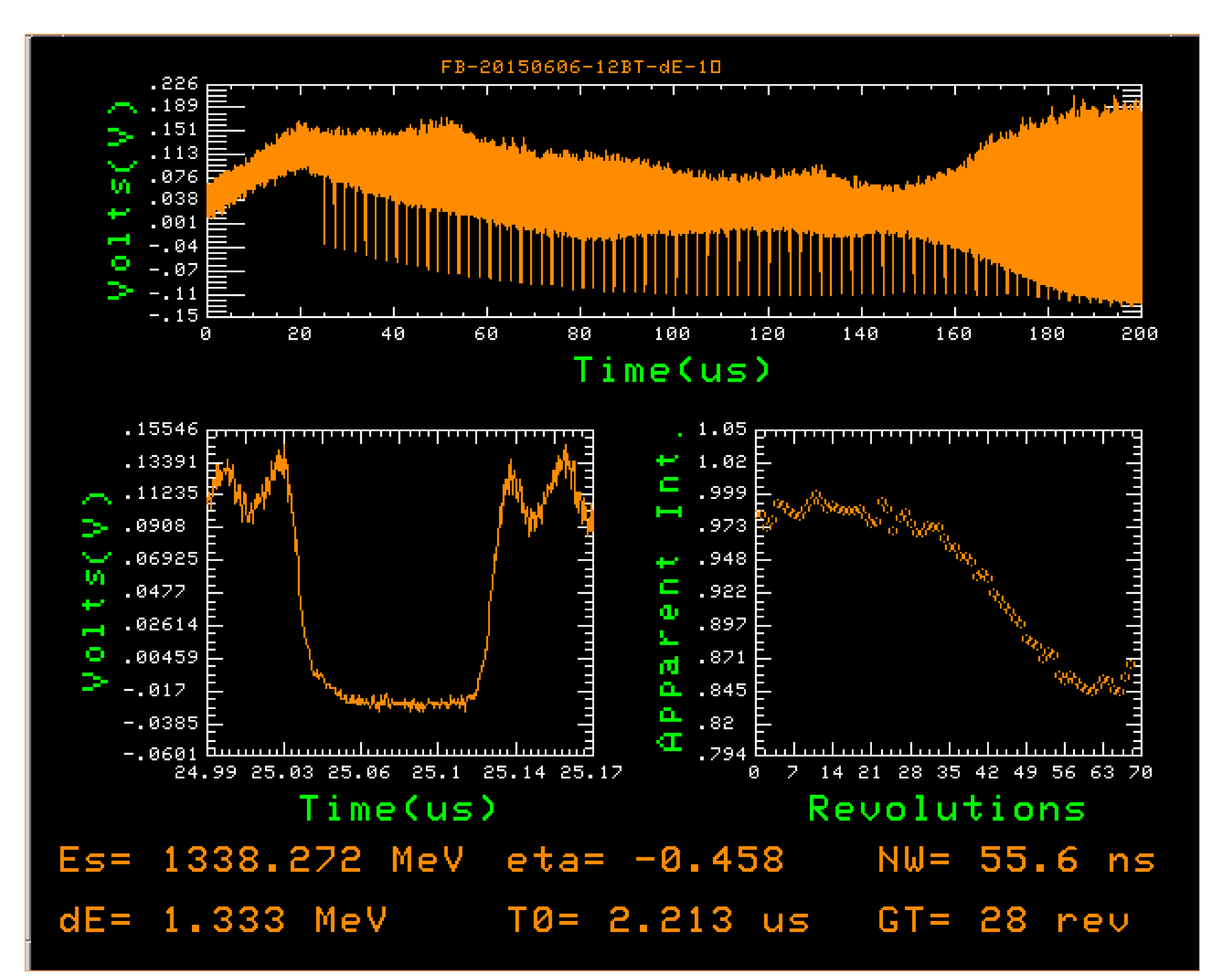


Analysis Method

An algorithm to analyze the early notch data was first written in Python and can be seen in the figures above. The values that were calculated are the revolution period, grazing touch (Tgraze) of the high momentum particles and low momentum particles, and the width of the first notch (Wnotch). Using $\Delta E = \frac{\beta^2 Es}{|\eta|}\frac{Wnotch}{Tgraze}$ where β is the relativistic velocity, Es is the synchronous and η is the slip factor, the energy spread is calculated.

ACNET Application Program

The program flow chart depicts the basic idea of the Booster energy spread measurement. It is written for the FNAL ACNET console environment. The program adopts all the features of the program written in Python and much more. Its outputs are beam energy, the measured energy spread(ΔE), Booster slip factor at injection energy, measured revolution period, the notch width, and the number of revolutions for grazing touch. It also plots the raw data (top), notch in the beam and an apparent beam intensity used to determine the grazing touch.



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References: 1) *FNAL Booster Rookie Book*, 2) C. M. Bhat, et al., IPAC2I015 (2015), THPF113.